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Germplasm screening of pearl millet (*Pennisetum glaucum*) for popping characteristics

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ABSTRACT

Thirty eight germplasms/varieties of pearl millet (*Pennisetum glaucum* L. R Br) were screened for popping characteristics at optimum processing conditions. For determining optimum processing condition, popping experiment of pearl millet (PC 443) was initially carried out as per central composite rotatable design in response to surface methodology with three factors (moisture content, tempering time and popping temperature) at five levels. Optimum conditions for maximum popping yield (62%) was determined as 15.92% moisture content, 7.16 h tempering time, and 282°C temperature. The popped grains were found to have good nutritional value with 11.2% protein, 7.36% fat, 2.96% crude fibre, 3.83% ash, 72.81% carbohydrate, and total antioxidant 15.47 µ mole Trolox /100 g. Popping significantly reduced anti-nutritional factor to a level of 373.82 mg/100g phytic acid. Based on popping characteristics like popping yield, puffing index and size of popped grain, seven germplasms/varieties, viz. IC 283734, IC 283745, IC 283763, IC 283842, IC 283908, 841-B and PPMI 301 were found to have potential popping trait.

Key words: Germplasms, Pearl millet, Physico-chemical properties, Popping

Popping of grains is a very common practice in the country. Popped grains especially popped rice and pop-corn, are widely consumed as ready-to-eat snacks and are also used to develop many snack formulations. Some of the grains like wheat, oat, bengal gram, barley, amaranth seeds, ragi, sorghum etc are more commonly used for popping but the popping of millets has not received high attention yet. This is despite the fact that these grains, also being called as nutri-cereals, are power house of nutrients. Since popping of whole grains is one of the popular mode of consumption as snack in the country, popped pearl millet (*Pennisetum glaucum* L. R Br) can find good scope among consumers and entrepreneurs, especially at small scale.

For popping of grains, appropriate conditioning, popping temperature etc are required. Previous studies have suggested the varying popping conditions for different grains. For popping of ragi, the optimum conditions were found as 19% moisture content (w.b.), moisture equilibration time of 4 hr and puffing temperature of 270°C (Malleshi and Deshikachar 1981). Puffing of naked barley at a moisture content of 16.5% (w.b.) gave the maximum puffing index (Hoke *et al.* 2007). The optimum popping conditions for paddy was reported as moisture content of 14% (w.b.) for sand puffing at about 200°C. However, pre-treatment of paddy with soaking in 2% NaCl solution (optimum concentration) led to shift in its optimum moisture content from 14% to 17% (w.b.) with better expansion (Murugesan and Bhattacharya 1986).

The objective of the present study was to optimize the popping conditions for pearl millet (PC 443) and to evaluate the varieties/germplasms of pearl millet for popping characteristics.

MATERIALS AND METHODS

The pearl millet grains were obtained from the farms of Indian Agricultural Research Institute, New Delhi as well as National Bureau of Plant Genetic resources, New Delhi. Grains were cleaned thoroughly. Popping of pearl millet (PC 443) grain was done with the traditional/conventional method using iron pan. Salt was used as heating medium. The effect of moisture content, tempering time and salt temperature was determined on popping yield of the grain. Popping experiment was conducted as per central composite rotatable design in response surface methodology with 3 factors (moisture content, tempering time and popping temperature) at 5 levels. The design consisted of 20 trials. The ranges of variable levels were selected on the basis of preliminary popping trials. The experiment was conducted as shown in Table 1.

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Table 1 Response surface design for evaluation of popping characteristics of pearl millet

Moisture content (%) (w.b.)	Tempering time(hr)	Popping temperature (°C)
–1 (16)	–1 (4)	–1 (190)
1 (20)	–1 (4)	–1 (190)
–1 (16)	–1 (4)	1 (270)
1 (20)	–1 (4)	1 (270)
–1 (16)	1 (8)	–1 (190)
1 (20)	1 (8)	–1 (190)
–1 (16)	1 (8)	1 (270)
1 (20)	1 (8)	1 (270)
–1.682 (14.6)	0 (6)	0 (230)
1.682 (21.4)	0 (6)	0 (230)
0 (18)	0 (6)	–1.682 (163)
0 (18)	0 (6)	1.682 (297)
0 (18)	–1.682 (2.6)	0 (230)
0 (18)	1.682 (9.4)	0 (230)
0 (18)	0 (6)	0 (230)
0 (18)	0 (6)	0 (230)
0 (18)	0 (6)	0 (230)
0 (18)	0 (6)	0 (230)
0 (18)	0 (6)	0 (230)
0 (18)	0 (6)	0 (230)

Values within parentheses indicate actual values of variables whereas outside parentheses are coded values

The popping conditions were standardized first for maximum popping yield, puffing index and expansion ratio of pearl millet. At the optimized conditions, 15 other varieties and 23 germplasms of pearl millet were tested for their popping characteristics.

The popping yield of the pearl millet grain was determined using Eq 1 (Malleshi and Desikachar 1981).

$$\text{Popping yield (\%)} = \frac{\text{Weight of popped grains}}{\text{Weight of (popped + unpopped) grains}} \times 100 \qquad ...(1)$$

Puffing index is the ratio of the bulk density of the raw material and the bulk density of the product. Higher puffing index indicates higher volume of the product. The puffing index was calculated using equation 2 (Hoke *et al.* 2007).

$$\text{Popping index} = \frac{\text{Bulk density of raw grain}}{\text{Bulk density of popped grain}} \qquad ...(2)$$

Expansion ratio is the ratio of size of popped grain to the size of raw grain. The expansion ratio was calculated by equation 3 (Mariotti *et al.* 2006). For size, breadth of grain was taken as the maximum expansion in size occurred in breadth after popping.

$$\text{Expansion ratio} = \frac{\text{Breadth of popped grain}}{\text{Breadth of raw grain}} \qquad ...(3)$$

The nutritional content (protein, fat, crude fibre) of the popped grain was evaluated as suggested in AOAC (1990). Ash content of the samples was determined using muffle furnace (AACC 1983). The carbohydrate content was calculated by the difference method. The phytic acid was estimated by the method suggested by Sadasivam and Manickam (1991). Anti-oxidant activity was determined by CUPRAC method (Apak *et al.* 2004).

RESULTS AND DISCUSSION

The popping of pearl millet (PC 443) was carried out at varying grain moisture contents, tempering time and temperature. After popping, some grains pooped whereas few remained unpopped, as shown in Fig 1. The important popping characters like popping yield, puffing index and expansion ratio were determined.

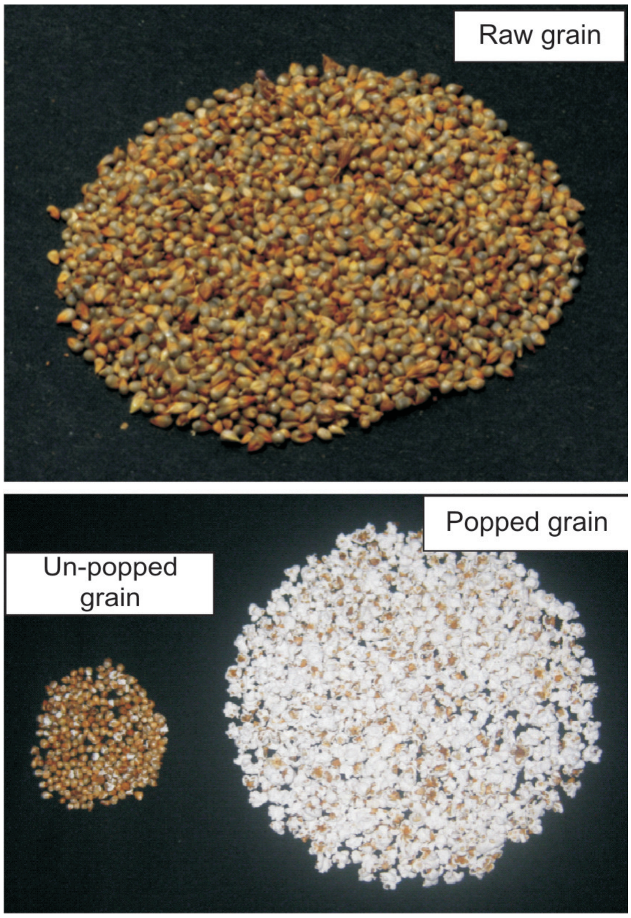

Fig 1 Raw, popped and un-popped grains of pearl millet (PC 443)

Popping yield

Effect of temperature on popping yield of raw grain is presented in Table 2. It was observed that the popping yield varied from 13-35% with increase in temperature from 162-297°C. Thus, maximum 35% popping yield could be achieved, which is very low.

To increase the popping yield, moisture conditioning treatment was given to the grain and the conditioned grain was popped at varying temperatures. The popping yield of pearl millet (PC 443) thus varied from 51.85 to 64.93%. It was also observed that the popping time was dependent upon the amount of feed and popping temperature. Generally,

Table 2 Effect of temperature on popping yield of raw grain

Popping temperature (°C)	Popping yield (%)
162	13.9
190	18.5
230	24.2
270	32.5
297	35.1

it was found between 15 and 22 s. The popping yield of pearl millet increased with increase in moisture content and temperature up to certain range but decreased thereafter, as evident from presence of quadratic term in Eq 4. Same effect was also observed by Malleshi and Desikachar (1981) in popping of ragi. They observed that there was an optimum moisture content, tempering time and temperature up to which an increase was found in the popping yield of ragi and then it reduced.

A relationship (Eq 4) in terms of coded levels of variables for prediction of popping yield from pearl millet was obtained by fitting second order polynomial with experimental data using multiple regression. Coefficient of determination (R^2) of 0.57 indicated that only 57% variability in popping yield could be explained by the variables. Popping yield was found to be linear function of moisture content and tempering time and temperature. Positive coefficients of temperature and tempering time show that popping yield increased linearly with their increase up to certain limit. Presence of quadratic terms of these variables with negative coefficients indicates decrease in popping yield after a limit. However, negative coefficient of moisture content indicated that popping yield decreased with increase in moisture content. Coefficient of term indicated maximum influence of tempering time on popping yield followed by temperature and moisture content.

$$P_y = 60.27-1.03M+1.38T+1.39t-0.71M^2-0.23TM-0.47T^2 -0.25tM-0.64tT-0.68t^2 \ (R^2=0.57) \quad \ldots(4)$$

where, P_y, Popping yield (%), M, moisture content (%wb), T, temperature (°C), t, tempering time (h).

For optimization of parameters for maximum popping yield, stationary point was calculated. The value of stationary point was calculated as –1.04 (15.92%) moisture content, 1.31 (282.4°C) temperature and tempering time of 0.58 (7.16 hr). To determine the nature of the stationary point, canonical analysis was carried out. The Eigen (l) values obtained at the stationary points were –0.24, –0.61 and –1.01, i.e. all negative values, indicating the stationary point to be the maximum, i.e. maximum popping yield. Predicted popping yield at stationary point was 62.12%.

Puffing index

Higher the puffing index, higher is the volume of the puffed grains. Puffing index varied from 6.67 to 9.33. The puffing index decreased with increase in temperature, time and moisture content up to certain range, which is clear from linear terms in Eq 5. The results are in agreement with Hoke *et al.* (2007) who found that there was an increase in puffing index up to a moisture content of 16.5% (w.b.) and then it decreased during the puffing of the naked barley. They also found that for temperature increment from 450 to 600°C, there was a decrease in puffing index. Zapotoczny *et al.* (2006) also reported a decrease in puffing index of amaranth as the temperature increased from 290 to 370°C.

A second order polynomial was fitted with experimental data of puffing index (P_i) using multiple regression and the resulting equation is presented as Eq 5. As evident from coefficient of the terms in equation 5, moisture content had maximum influence on puffing index. High value of R^2 clearly indicated the adequacy of the model. Puffing index was found to be linear function of moisture content, tempering time and temperature as evident from negative coefficient. However, presence of quadratic terms of the variables reveal that linearity of change in puffing index is limited to limited range of variables beyond which there is increase or decrease depending upon positive or negative coefficient.

$$P_i = 8.45-0.71M-0.11T-0.32t-0.09M^2-0.18TM + 0.06T^2-0.14tM-0.09tT-0.09t^2 \ (R^2=0.91) \quad \ldots(5)$$

Expansion ratio

It indicates the increase in size of the grain after popping. Higher size of the product is more desirable. The size of popped grain was measured at the optimum condition where maximum popping yield was obtained. It was found that there was 25.35% increase in length of the grain after popping (3.275 to 4.387 mm), whereas 67.05% in width (2.19 to 6.647 mm) and 57.14% in thickness (1.93 to 4.503).

The expansion ratio varied from 2.44 to 3.04. There was increase in expansion ratio with increase in temperature and tempering time but decreased with increase in moisture content. The findings are well supported by Murugesan and Bhattacharya (1986) who found that there was an optimum temperature up to which the increase in expansion took place and reduced thereafter. They observed high expansion of paddy in the temperature range of 190 to 210°C. Same trend was observed also by Chinnaswamy and Bhattacharya (1983) in popping of milled parboiled rice who observed optimum moisture content of 10.5% (w.b.) to achieve highest expansion. Zapotoczny *et al.* (2006) too found that there was a decrease in size of the puffed grain as the temperature increased from 290 to 370°C during the puffing of amaranth seeds.

Nutritional evaluation of raw and popped grain

The proximate composition of raw and popped grain of pearl millet (PC 443) was determined and is shown in Table 3. There was an increase in fat, crude fibre, ash and carbohydrate contents of the popped grain, it was due to increased concentration of these nutrients as the moisture was lost (7.74 to 1.84%) during popping. However, there was decrease in protein content and total anti-oxidants during popping. There was a significant reduction in phytic acid content (anti-nutritional factor) from 516.37 to 373.82

Table 3 Nutritional composition of raw and popped pearl millet grain (PC 443)

Composition	Raw grain	Popped grain
Moisture, %	7.74	1.84
Protein, % (db)	12.14	11.41
Fat, % (db)	5.19	8.28
Crude fibre, % (db)	1.95	3.19
Ash, % (db)	1.69	3.95
Carbohydrate, % (db)	74.16	75.71
Total antioxidant, µ mole Trolox/100 g	22.05	15.47
Phytic acid, mg/100g	516.37	373.82

Table 4 Popping characteristics of varieties/germplasms of pearl millet

Variety/ germplasm	Popping yield (%)	Puffing index	Size of popped grain (mm)
IC 283693	50.47	6.72	6.66
IC 332707	68.35	8.20	6.81
IC 332706	50.38	6.67	6.76
IC 283763	75.43	9.38	6.21
IC 332715	53.16	9.84	5.56
IC 283737	63.73	8.48	7.45
IC 283734	76.23	10.31	8.84
IC 283702	60.58	8.33	5.92
IC 283681	64.70	8.21	7.27
IC 283692	69.44	8.03	6.36
IC 309055	66.95	8.13	4.67
IC 283882	69.35	8.05	6.61
IC 283908	76.96	10.55	7.05
IC 283745	71.05	8.65	5.29
IC 312753	64.83	9.23	7.05
IC 284848	61.35	8.13	7.19
IC 283749	66.55	8.59	6.61
IC 283818	65.72	7.80	5.64
IC 283847	65.74	9.68	7.11
IC 283744	61.35	9.21	7.54
IC 283769	67.61	8.31	6.64
IC 283893	57.12	8.13	6.06
IC 283842	74.26	7.91	6.70
IC 309060	58.52	8.19	4.36
PC 443	62.00	8.83	6.65
Pusa 605	62.16	9.19	6.63
Pusa 415	67.98	9.39	6.63
Pusa 322	57.96	7.74	6.17
576-B	69.73	8.13	5.37
841-B	79.28	8.06	4.90
Pusa 612	54.75	6.17	4.93
Pusa 383	59.86	7.03	5.08
K 560-230	48.23	6.62	5.39
D 23	48.26	5.37	5.61
Pusa 621	67.37	6.92	6.03
PPMI 69 S	68.09	8.46	5.81
PPMI 301	75.73	7.42	5.11
PPMI 85	66.04	7.69	5.29

mg/100g, which may be ascribed to the heat treatment.

Popping of different varieties and germplasms of pearl millet

Thirty eight germplasms/varieties of pearl millet (Table 4) were evaluated for their popping characteristics. The 1000 kernel weight of these germplasms showed wide variation from 5.08 g to 15.95 g. Popping was carried out at the optimum conditions, determined for PC 443 variety of pearl millet.

The size of popped grains of different germplasms/ varieties varied from 4.36-8.84 mm (width as major dimension), popping yield ranged from 48.23 to 79.28% and puffing index varied between 5.37 and 10.55. The germplasm/varieties were further grouped into three clusters on the basis of popping characters using hierarchical clustering method as shown in dendogram (Fig 2). Seven germplasm namely IC 283734, IC 283745, IC 283763, IC 283842, IC 283908, 841-B and PPMI 301 with the highest mean popping yield of 75.56 per cent and puffing index of 8.90 were grouped in one cluster which indicates their

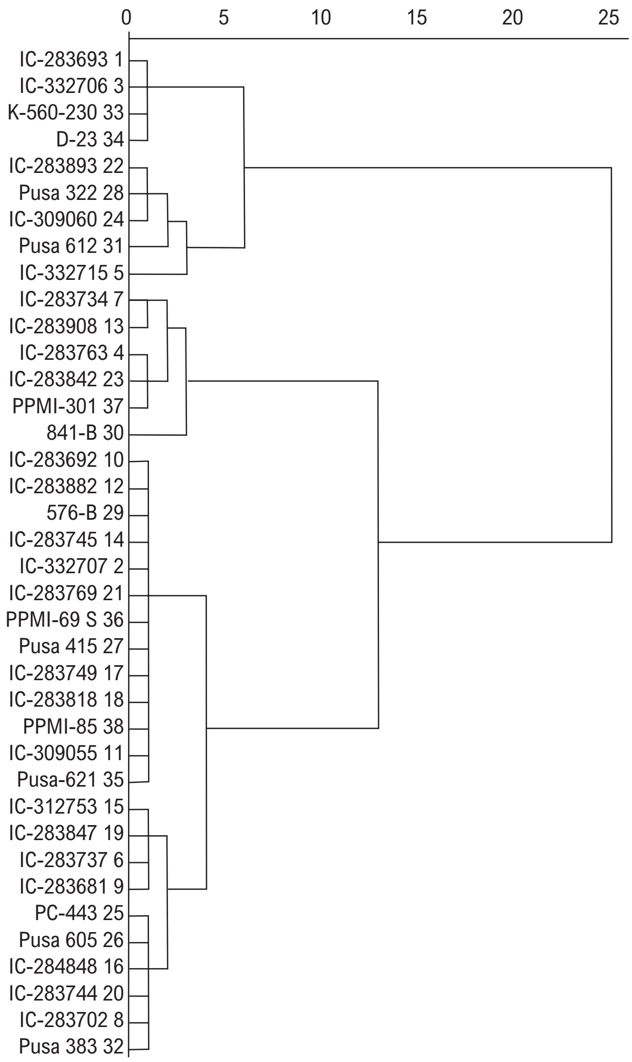

Fig 2 Dendogram for distances in popping characters between pearl millet germplasm/varieties

potential for popping. Popping being an important trait can add to commercial value to the grain. The finding can be useful in breeding programme for the plant breeders.

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